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ILS Mathematical Modeling Study of the Effects of an ASR-9 Structure at the Long Island MacArthur Airport, Islip, N. Y., Runway 24

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September 1992

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16. Abstract

This Technical Note describes the instrument landing system (ILS) math modeling performed by the Federal Aviation Administration (FAA) Technical Center at the request of the Eastern Region. Computed localizer data are presented showing the effects of an ASR-9 antenna structure proposed for construction on the performance of an ILS localizer serving runway 24 at the Long Island MacArthur Airport. The ASR-9 antenna structure was modeled at four proposed sites. The Eastern Region is concerned that radio frequency signal reflections from the ASR-9 structure may degrade the localizer course. Modeled course structure results indicate that Category I localizer performance should be maintained with the Wilcox 8-element log periodic dipole antenna with the ASR-9 structure constructed at any of the proposed locations. The ASR-9 structure provided minimal signal interference at each site modeled. Computed clearance orbit results indicate satisfactory linearity, course crossover, and signal clearance levels.

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EXECUTIVE SUMMARY

This instrument landing system (ILS) math modeling study was performed at the request of the Eastern Region to compute the effects of an ASR-9 structure proposed for construction on the performance of an ILS localizer serving runway 24 at the Long Island MacArthur Airport. The localizer was modeled using a physical optics mathematical model developed by the Transportation Systems Center and extensively modified by Ohio University. As requested by AEA-451, a Wilcox 8-element log periodic dipole antenna array was modeled. Derogative effects from a proposed ASR-9 antenna structure was the only reflecting source considered in this modeling study. The ASR-9 structure was modeled at four proposed locations and on several rotated angles. Modeled course structure results indicate that Category I localizer performance should be maintained for runway 24 with minimal signal interference from the ASR-9 structure constructed at any of the proposed locations. Computed clearance orbit results indicate satisfactory linearity, course crossover, and signal clearance levels.

INTRODUCTION

PURPOSE.

The purpose of this math modeling study was to provide computer modeled performance data for an instrument landing system (ILS) localizer serving runway 24 at the Long Island MacArthur Airport.

BACKGROUND.

The Eastern Region, AEA-451, is concerned that signal reflections from an ASR-9 structure proposed for construction at the Long Island MacArthur Airport may degrade the runway 24 ILS localizer performance. AEA-451 has requested a math modeling study through the ILS Program office, ANN-200, which, in turn, was forwarded to the Federal Aviation Administration (FAA) Technical Center for accomplishment. Localizer math modeling was requested for an ASR-9 structure proposed for construction at four locations to determine if this structure derogates the runway 24 localizer performance. Runway 24 is serviced by a Wilcox 8-element log periodic dipole (LPD) antenna array providing Category I localizer performance. This modeling effort was performed under project T0603S. The Technical Program Manager is Mr. Edmund A. Zyzys. Additional information regarding this study may be obtained by contacting Mr. James D. Rambone at (609) 484-5373.

DISCUSSION

ILS MATH MODELS.

The FAA Technical Center conducts ILS mathematical computer model studies through application of physical optics or geometric theory of diffraction techniques to compute anticipated ILS performance. The modeling for the runway 24 localizer was performed using the physical optics model, which was developed by the Transportation Systems Center (TSC), modified extensively by Ohio University, and then converted to the Technical Center's mainframe computer. References 1 through 4 describe the modeling technique and implementation. Reference 4 also provides validation data for the model.

This model operates using the physical optics principles by considering the structure or aircraft as a target or reflector. The reflecting object is modeled by considering it to be a collection of flat plates, whose profile is that of the specific structure. The flat plate representing the structure is located with a specified orientation and location on the airport.

This flat plate may be divided up into arbitrarily small areas, each of which is receiving incident electromagnetic radiation from the transmitting antennas. The incident signals arrive at the respective incremental area with a specific amplitude and

phase which are dependent on the phase and amplitude of the source currents in the transmitting antennas and the path length from the antennas to the incremental area on the plate. The fields are, in effect, terminated by currents in the conducting surface so that the boundary conditions at the conducting surface are met. These currents flowing in the incremental plate, thus, become source currents for the scattering signal.

Figure 1 illustrates the right-handed coordinate system used in this computer model with the origin located at the antenna site for localizer modeling and the runway point intercept (RPI) for glide slope modeling. The positive x-axis is directed out beyond the threshold along runway centerline extended, the positive y-axis is directed to the left, and the positive z-axis is directed up. Alpha, the angle between the base of a reflector and the x-axis, is measured in the counterclockwise direction. Delta is the angle between the surface of the reflector and the vertical direction. The large solid arrows in the figure point in the direction that the reflecting surface faces. A reflector facing in the negative y-direction has an alpha of 0 degrees. A reflector with a delta of 0 degrees is perpendicular to the ground (figure 1A). Delta is equal to -90 degrees for a horizontal reflector facing down (figure 1B). An alpha of 90 degrees, as shown in figure 1C, faces the reflector out along the positive x-axis. The reflecting surface is considered to be of infinite conductivity over the total surface and to have zero thickness. This assumption will result in a worst-case performance prediction. As previously indicated, the predicted radiation is calculated assuming an array of incremental, flat-plate antennas each with its own radiation pattern.

Course deviation indicator (CDI) deflections are computed as follows. First, the magnitude and phase of the radio frequency (RF) signals arriving at the aircraft location are determined for each surface independently. Next, a resultant RF signal is computed by vectorially combining the independent signals. CDI deflection is then computed from the resultant RF signal.

Some limitations do exist with this particular model; however, the resultant errors due to these limitations or assumptions are considered small. One limitation in the model is that it does not compute multiple reflections or diffractions. Another limitation is the assumption that the terrain is level and perfectly smooth.

ILS MATH MODELING PERFORMED.

Figure 2 shows the general orientation of the runway and the four proposed locations of the ASR-9 antenna structure. The modified TSC physical optics model was used to model the effects of the ASR-9 structure on the runway 24 localizer performance. As requested, the Wilcox 8-element LPD antenna was modeled at the ILS localizer site. Table 1 summarizes the localizer model input data, including antenna currents and phases.

Localizer course structure and clearance orbit computer runs were made with the proposed ASR-9 structure (support structure and antenna) as the only reflecting source. The ASR-9 structure was modeled with two rectangular plates (each 24 feet wide and 95 feet high) to represent the surfaces of the support structure and antenna which would be illuminated by localizer signals. The entire structure was modeled at each of the proposed locations in two scenarios. The first scenario placed the surfaces of the structure and antenna parallel and perpendicular to the runway centerline. In the second scenario, the entire structure, including the antenna, was rotated counterclockwise (positive rotation) to an angle equal to the angle from the localizer antenna to the proposed structure location to minimize reflecting surface areas, as shown in the example in figure 3. Test cases were made with the support structure (79 feet high and 24 feet wide) in the positive rotation angle, while the antenna on top of the support structure (16 feet high and 24 feet wide) was modeled in 5-degree increments over a 30-degree sector (clockwise rotation).

DATA PRESENTATION.

Modeled output results for the localizer are provided on three types of plots: (1) course structure plots, (2) clearance orbit plots, and (3) carrier plus sideband (CSB) and sideband only (SBO) antenna pattern plots. The simulated flightpaths for the course structure runs are centerline approaches starting approximately 60,000 feet from runway threshold. The aircraft crosses the runway threshold at the threshold crossing height and continues at this altitude to a point just short of the stop end of the runway. Distances shown on the horizontal axis of the course structure plots are referenced to the approach threshold. Negative values are shown for distances between the threshold and the localizer. Positive values apply to distances on the approach path toward the outer marker. Angular values on the horizontal axes of the CSB and SBO antenna pattern plots and on the clearance orbit plots were run with flight arcs of 35,000 feet at altitudes of 1,000 feet with respect to the localizer site.

The vertical axes of the course structure and clearance orbit plots are the model output values of CDI deflection in microamps (μA) (0.4-second time constant applied for smoothing). The vertical axes of the antenna pattern plots use a relative scale with the pattern normalized to its peak value. The usual range for the vertical scale of modeled course structure data plots is +40 (fly left) to -40 (fly right) microamps. This range has been reduced to +10 to -10 microamps for the course structure plots provided in this study in order to better display small values of CDI deflection. This choice of scale eliminates the display of Category I limits from the plot and shows only the final segment of the Category II tolerance limits. Category III tolerance limits (not shown) extend the 5-microamp tolerance shown for Category II performance to a point on the runway 3,000 feet from

threshold. The limits then increase linearly to 10 microamps at a point which is 2,000 feet from the stop end of the runway.

Computed localizer performance results with the ASR-9 support structure and antenna as the only reflecting source modeled are provided in figures 4 through 13. Modeled course structure results are plotted in figures 4 through 11. Computed clearance orbit results are given in figure 12. Figure 13 shows computed CSB and SBO antenna pattern plots.

DATA ANALYSIS.

Localizer course structure results with the ASR-9 support structure and antenna modeled at site 1 with parallel/perpendicular surfaces (figure 4) and a 13-degree positive rotation of the surfaces (figure 5) show computed CDI deflections of +1.1/-0.6 μA and +0.3/-0.2 μA, respectively. Modeled results for the ASR-9 support structure and antenna modeled at site 2 with parallel/perpendicular surfaces (figure 6) shows +1.3/-2.7 μA excursions and with an 11-degree positive rotation of the surfaces (figure 7) shows CDI deflections of +0.3/-0.3 μA. Course structure results for the ASR-9 support structure and antenna modeled at site 3 with parallel/perpendicular surfaces (figure 8) and a 10-degree positive rotation of the surfaces (figure 9) show CDI deflections of +2.0/-3.3 μA and +0.4/-0.3 μA, respectively. Modeled results for the ASR-9 support structure and antenna modeled at site 4 with parallel/perpendicular surfaces (figure 10) shows +3.0/-3.0 μA excursions (+10.0/-5.5 μA excursions inside threshold) and with a 16-degree positive rotation of surfaces (figure 11) shows CDI deflections of +1.8/-1.8 μA. Test case course structure computer runs were made at each site with the 79-foot support structure in the positive rotation scenario with the 16-foot antenna on top of the support structure modeled in increments of 5 degrees over a 30-degree sector. The test cases provided, at most, an additional +/-1.0 μA to the existing excursions for the positive rotation scenarios modeled (plots not provided). A computed clearance orbit plot (figure 12) indicates satisfactory linearity and course crossover with very little disturbance on the 90 hertz side of the clearance level pattern. Figure 13 shows CSB and SBO antenna patterns for the Wilcox 8-element LPD antenna array without effects from structures.

CONCLUSIONS

Localizer modeled results indicate that Category I localizer performance should be maintained with the Wilcox 8-element log periodic dipole (LPD) antenna array with minimal effects from the ASR-9 structure constructed at any of the proposed locations. Computed clearance orbit results indicate satisfactory linearity, course crossover, and clearance levels.

REFERENCES

1. Chin, G., et al., Instrument Landing System Scattering, Report DOT/FAA-RD-72-137, 1972.

2. Chin, G., et al., User's Manual for ILSLOC: Simulation for Derogation Effects on the Localizer Portion of the Instrument Landing System, Report DOT/FAA-RD-73-13, 1973.

3. Chin, G., et al., Instrument Landing System Performance Prediction, Report DOT/FAA-RD-73-200, 1974.

4. Chin, G., et al., ILS Localizer Performance Study, Part I, Dallas-Fort Worth Regional Airport and Model Validation, Syracuse Hancock Airport, Report DOT/FAA-RD-72-96, 1972.

TABLE 1. LOCALIZER ANTENNA MODEL INPUT DATA SUMMARY

Localizer Antenna Type: Wilcox 8-element Log Periodic Dipole

Runway 24 Length (ft):	5999.0
Distance to Runway 6 End (ft):	1550.0
Frequency (MHz):	108.3
Site Elevation (ft m.s.l.):	84.8
Antenna Height (ft):	6.0
Course Width (deg):	5.31

8-element LPD Array

Ant. No.	Spacing (wave length)	Carrier+Sideband Amplitude	Carrier+Sideband Phase (deg)	Sideband Only Amplitude	Sideband Only Phase (deg)
4L	-2.51086	0.05500	180.00000	0.41600	180.00000
3L	-1.77240	0.14300	0.00000	0.70000	180.00000
2L	-1.03405	0.36300	0.00000	0.89000	180.00000
1L	-0.29565	1.00000	0.00000	1.00000	180.00000
1R	0.29565	1.00000	0.00000	1.00000	0.00000
2R	1.03405	0.36300	0.00000	0.89000	0.00000
3R	1.77240	0.14300	0.00000	0.70000	0.00000
4R	2.51086	0.05500	180.00000	0.41600	0.00000

ft = feet
MHz = megahertz
m.s.l. = mean sea level
deg = degree

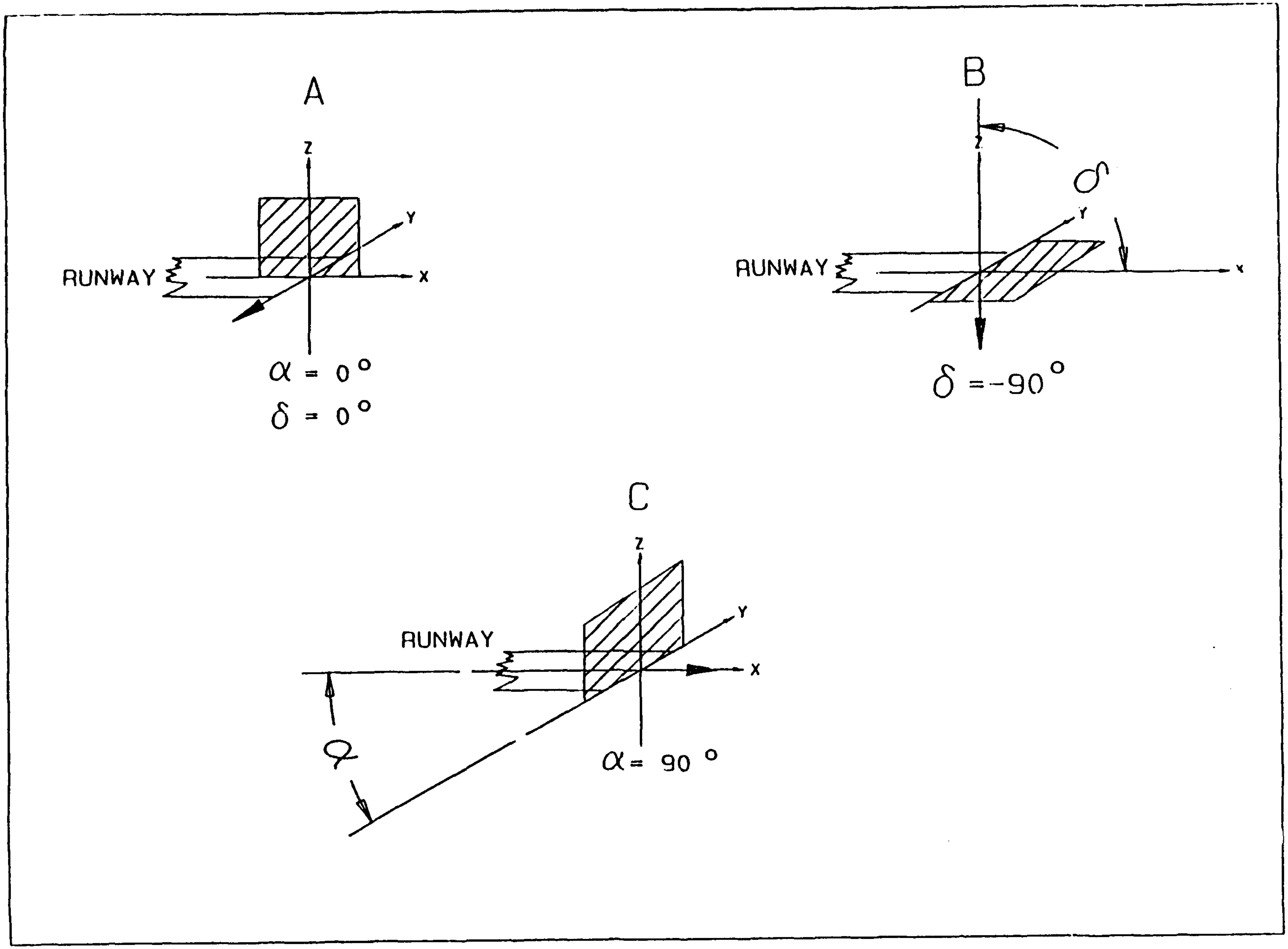

FIGURE 1. INSTRUMENT LANDING SYSTEM LOCALIZER MATH MODEL COORDINATE SYSTEM

	X*	Y*	Z*	WID	HT	ANGLE*
SITE 1	7800	1725	8	24*24	95	12.47
SITE 2	7640	1485	12	24*24	95	10.99
SITE 3	8170	1440	19	24*24	95	9.99
SITE 4	4200	1130	7	24*24	95	15.05

* REF FROM LOC (FT)

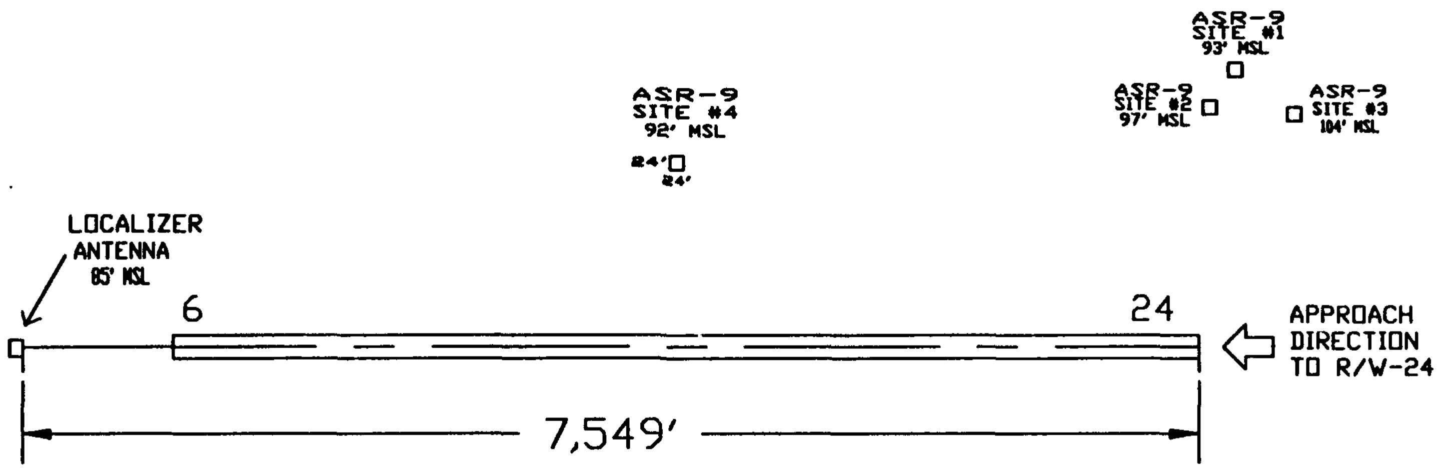

FIGURE 2. LONG ISLAND MACARTHUR AIRPORT RUNWAY 24, ILS MODELING LAYOUT

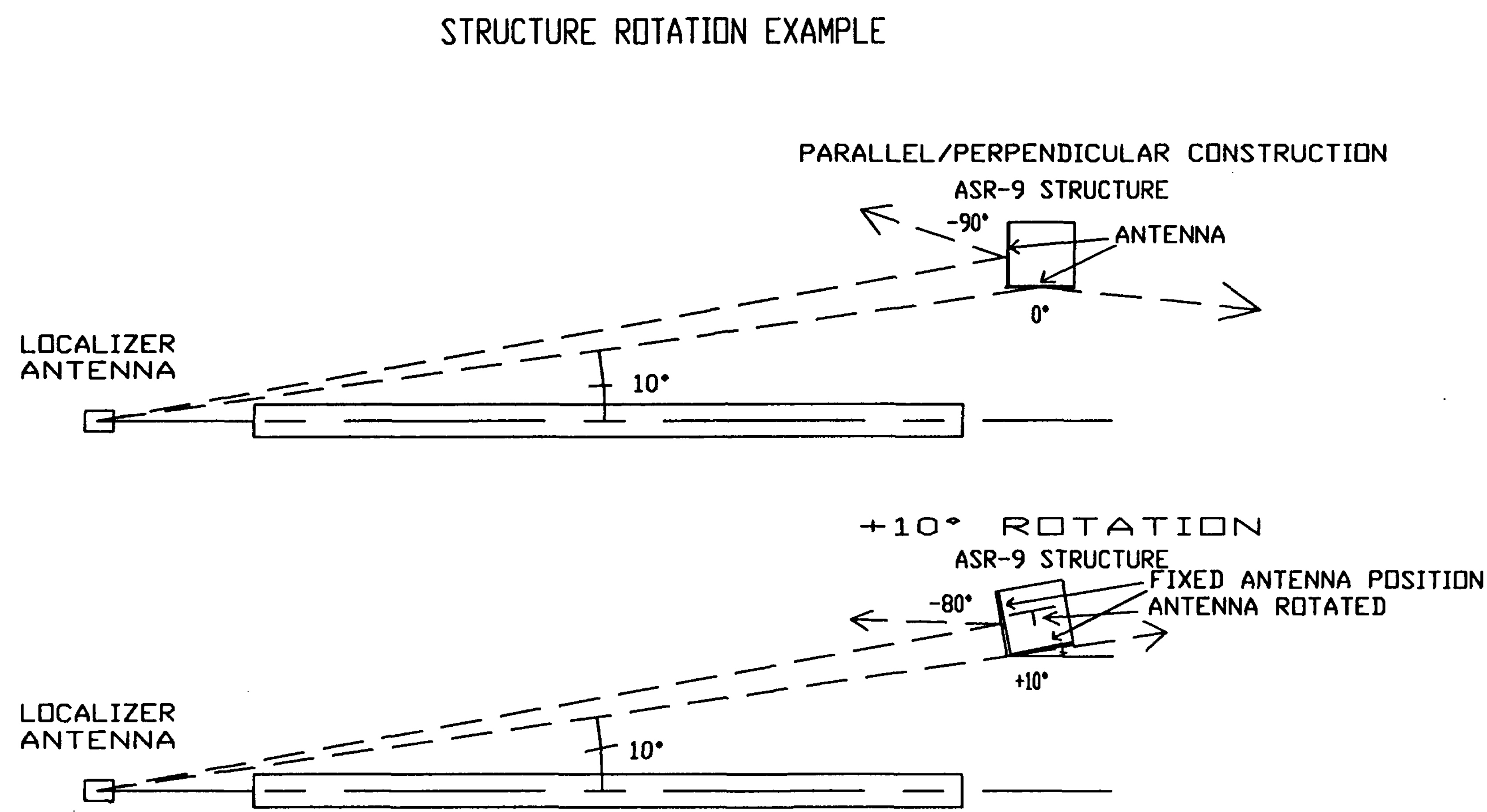

FIGURE 3. ASR-9 STRUCTURE, ROTATING SURFACE AND REFLECTING SIGNALS

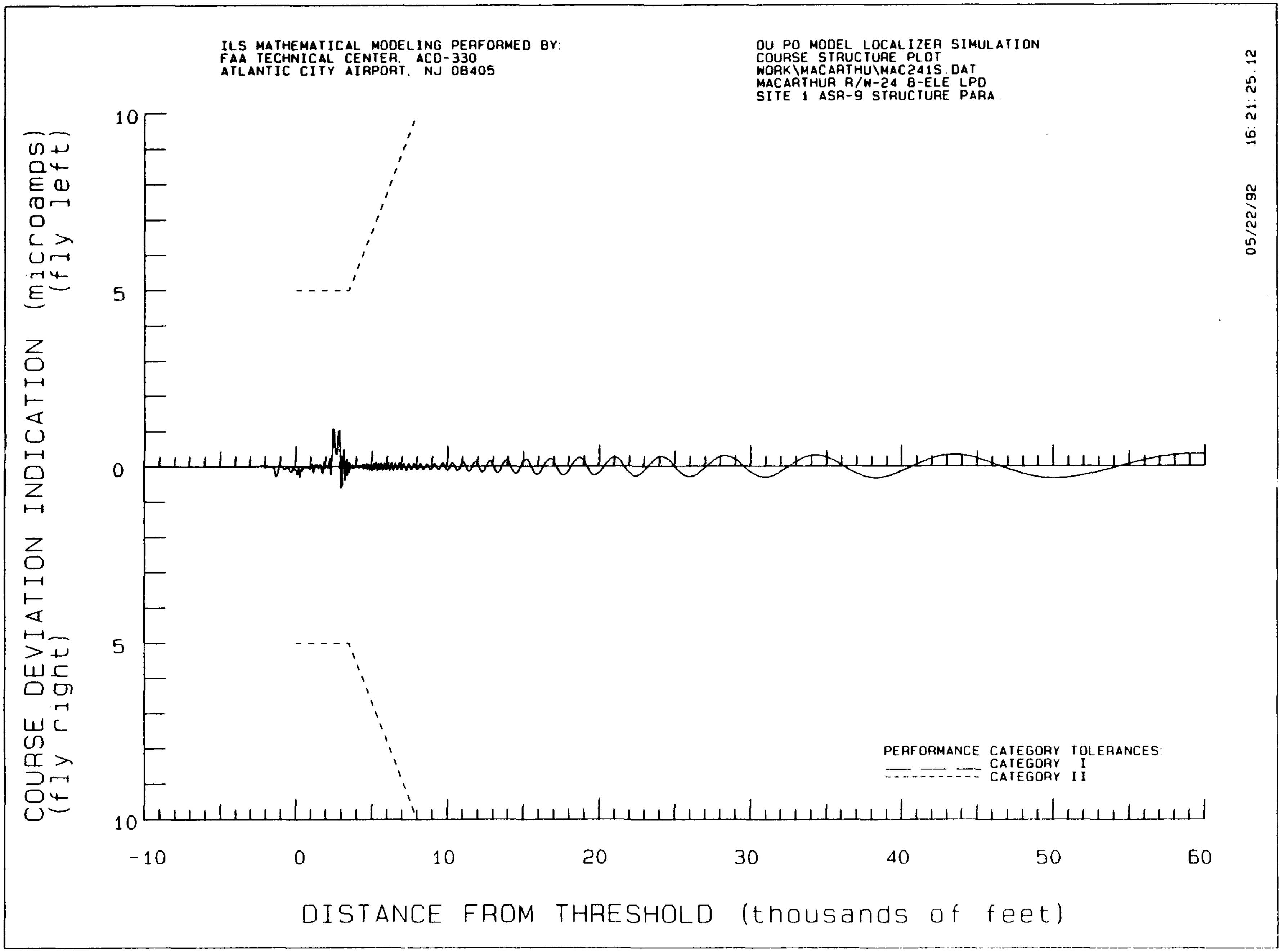

FIGURE 4. COURSE STRUCTURE, LONG ISLAND MACARTHUR AIRPORT RUNWAY 24, ASR-9 STRUCTURE PARALLEL, SITE 1

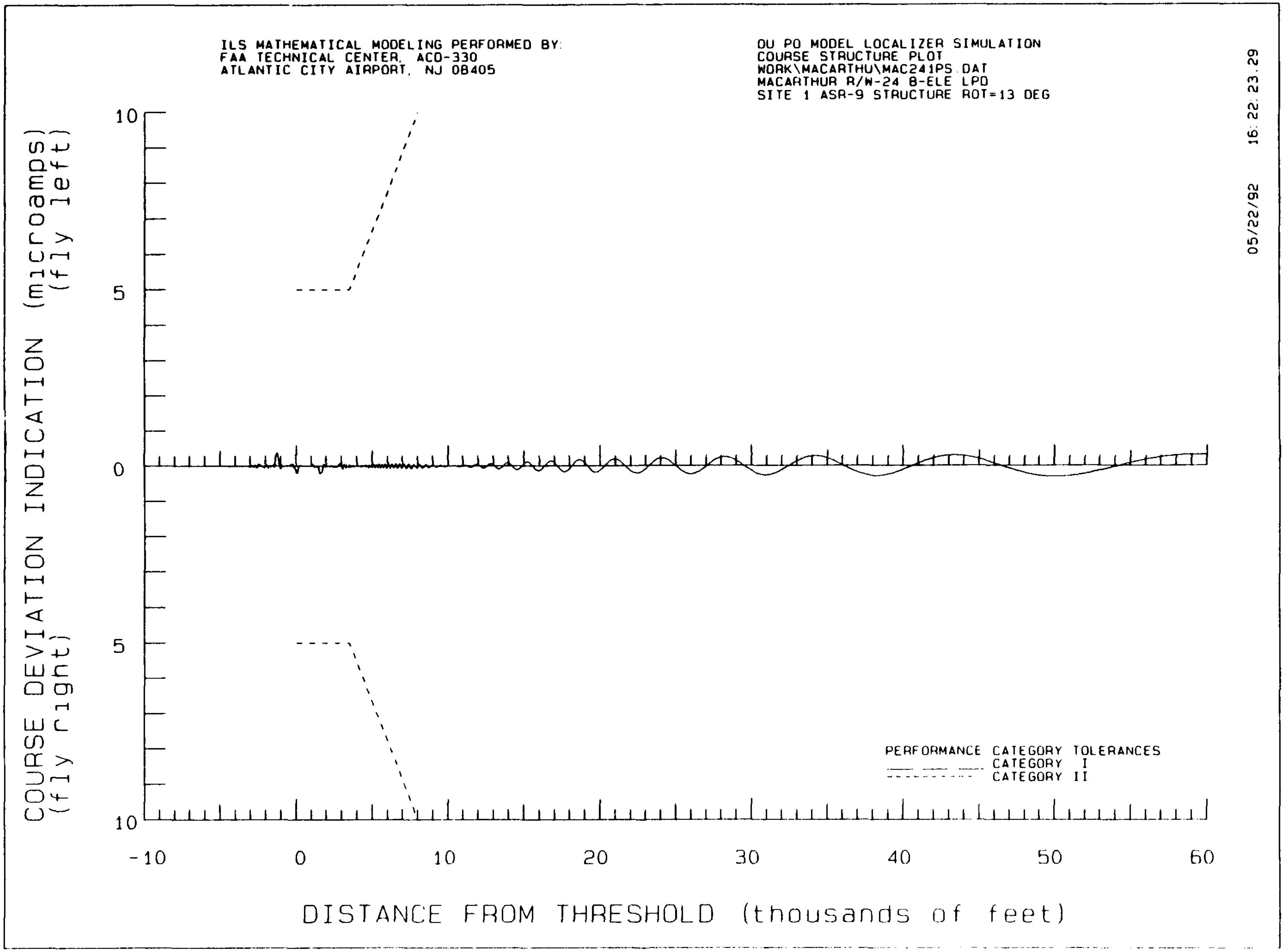

FIGURE 5. COURSE STRUCTURE, LONG ISLAND MACARTHUR AIRPORT RUNWAY 24, ASR-9 STRUCTURE +13 DEGREE ROTATION, SITE 1

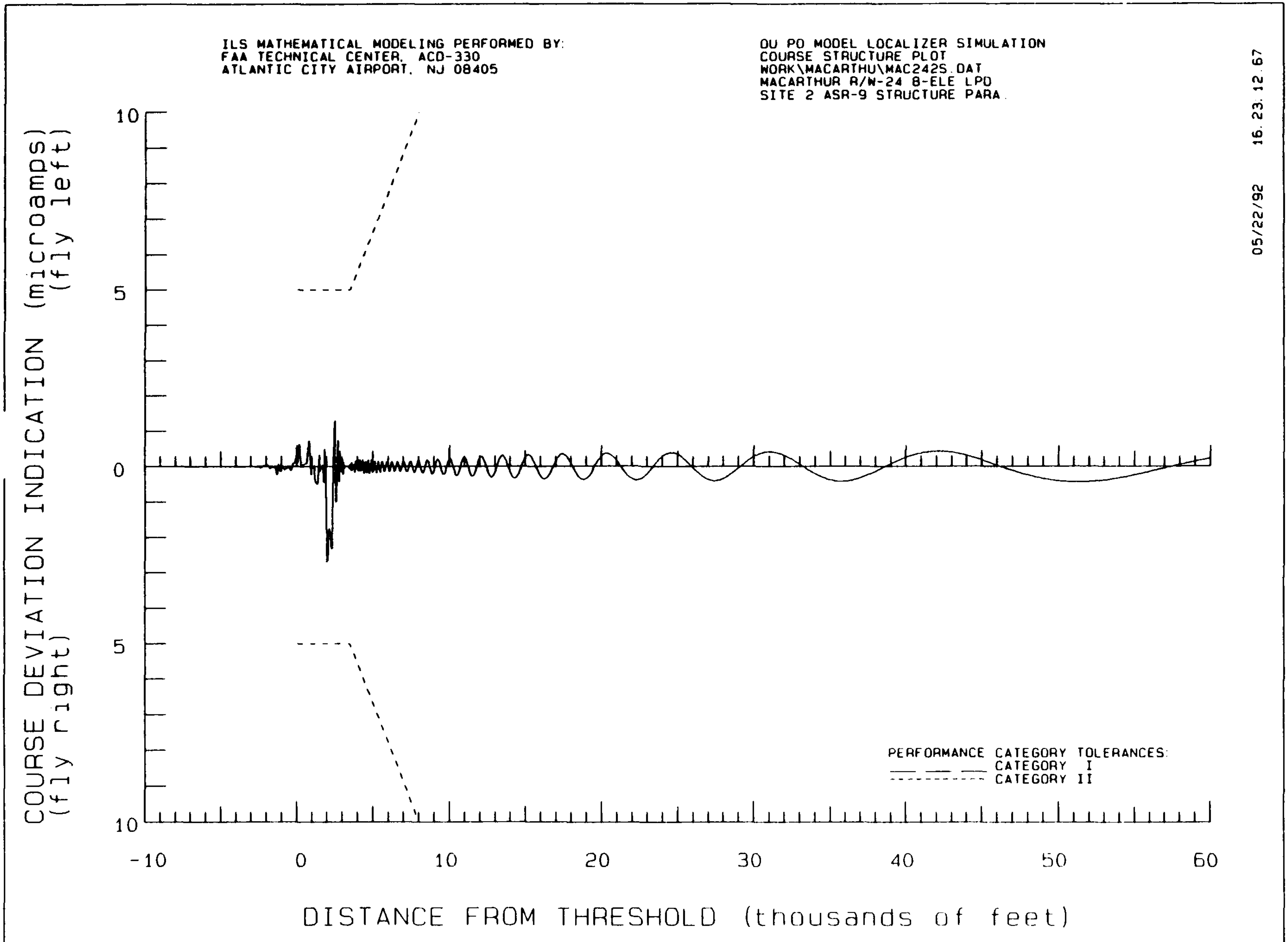

FIGURE 6. COURSE STRUCTURE, LONG ISLAND MACARTHUR AIRPORT RUNWAY 24, ASR-9 STRUCTURE PARALLEL, SITE 2

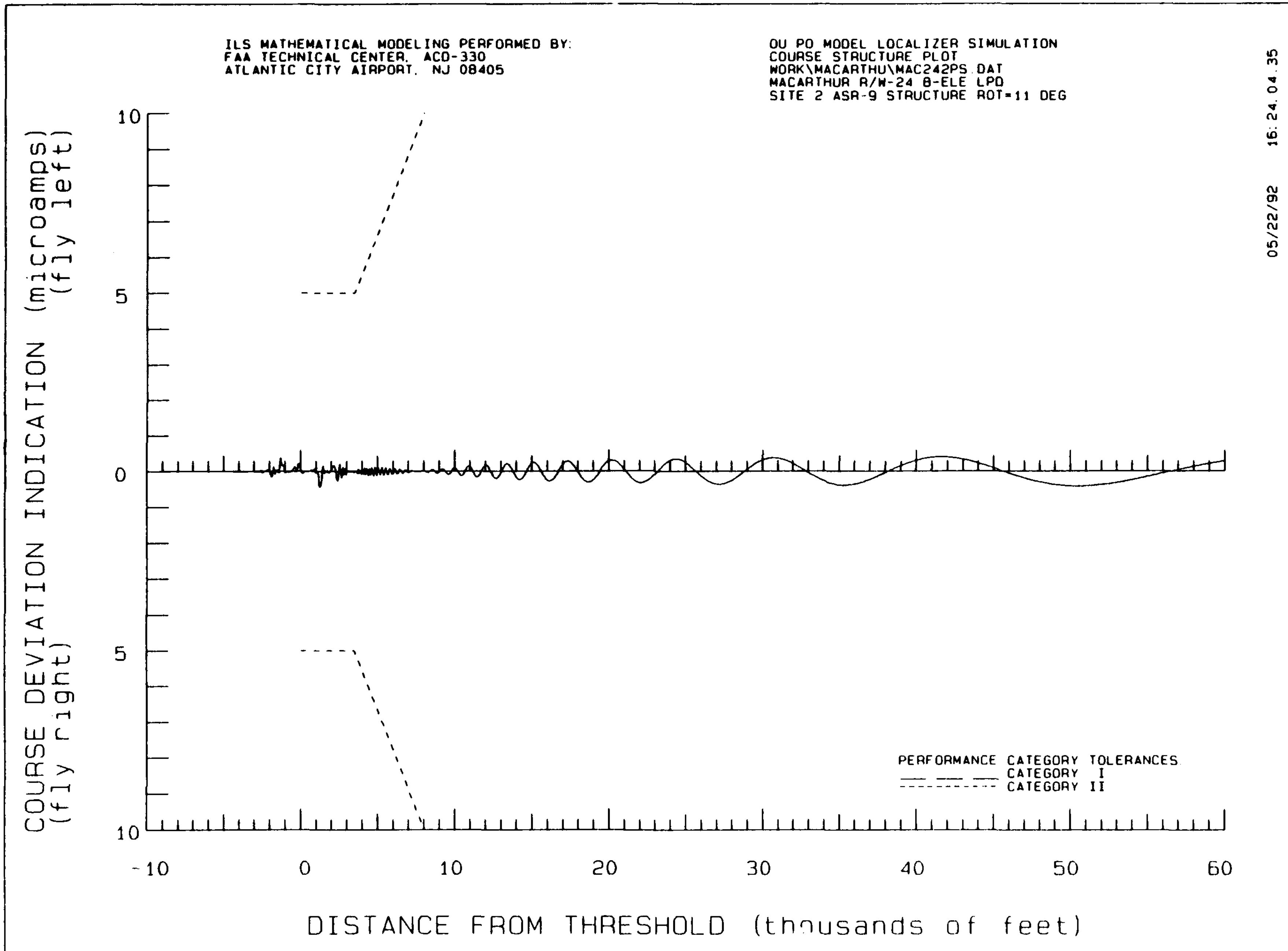

FIGURE 7. COURSE STRUCTURE, LONG ISLAND MACARTHUR AIRPORT RUNWAY 24, ASR-9 STRUCTURE +11 DEGREE ROTATION, SITE 2

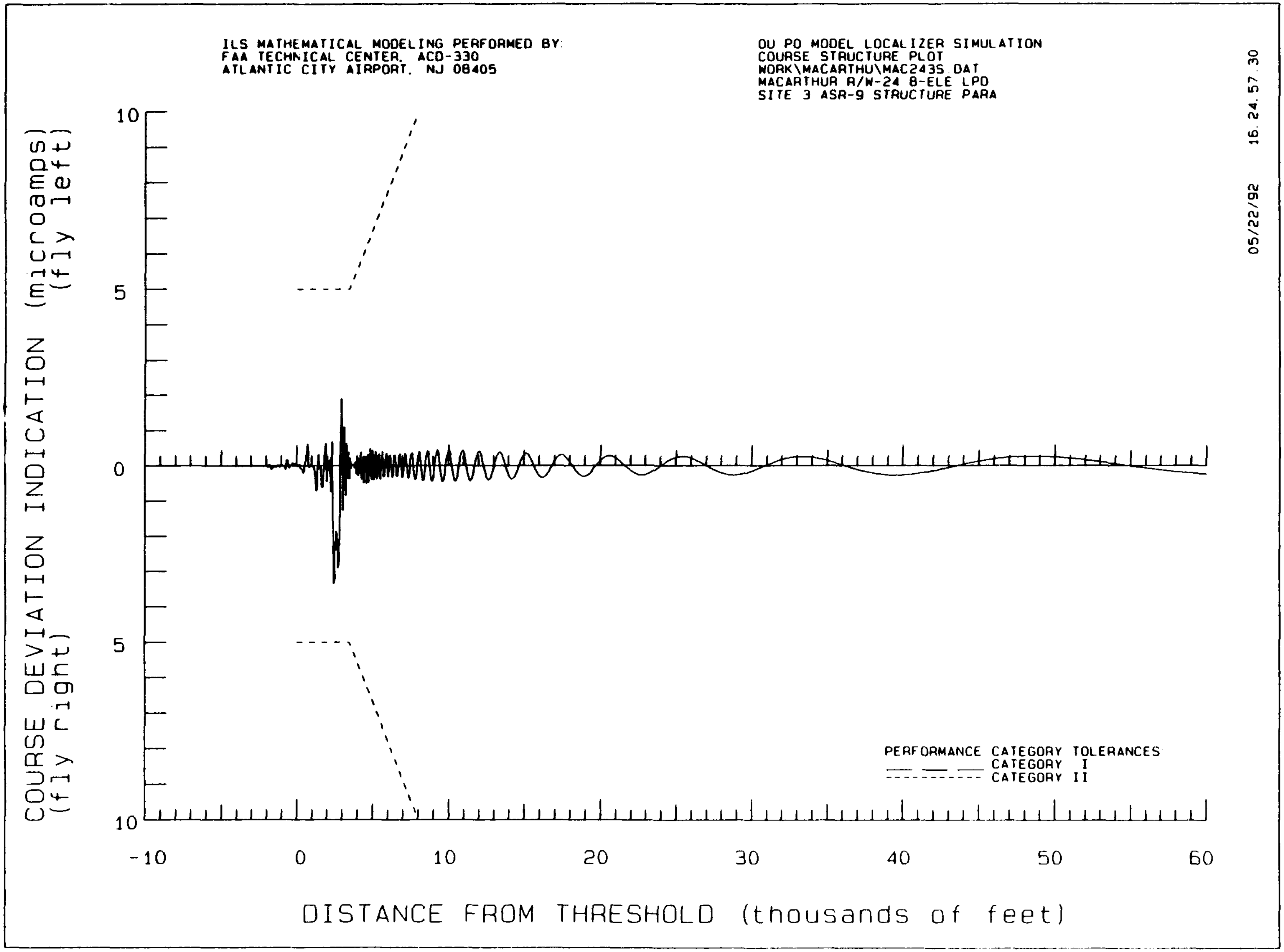

FIGURE 8. COURSE STRUCTURE, LONG ISLAND MACARTHUR AIRPORT RUNWAY 24, ASR-9 STRUCTURE PARALLEL, SITE 3

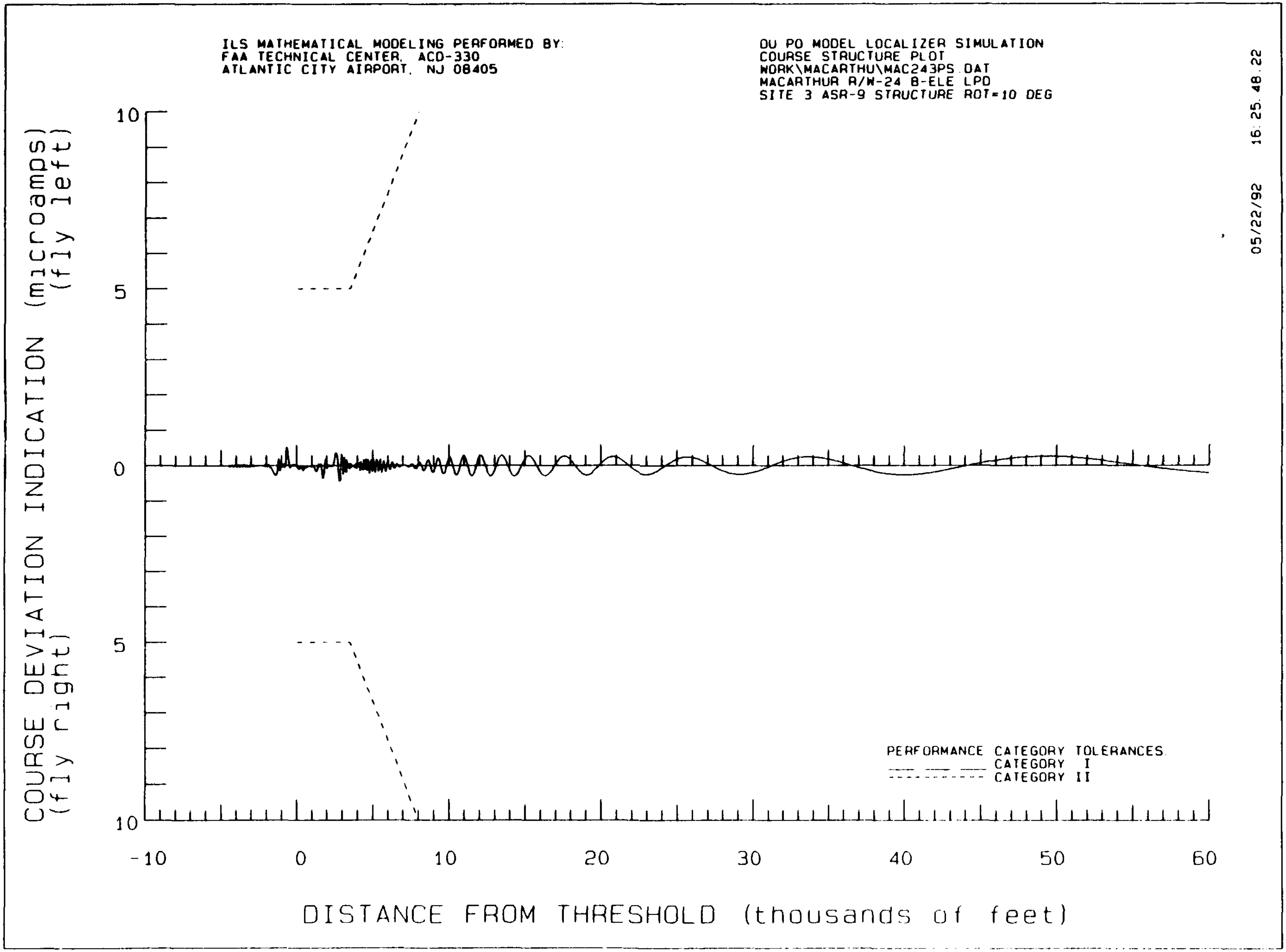

FIGURE 9. COURSE STRUCTURE, LONG ISLAND MACARTHUR AIRPORT RUNWAY 24, ASR-9 STRUCTURE +10 DEGREE ROTATION, SITE 3

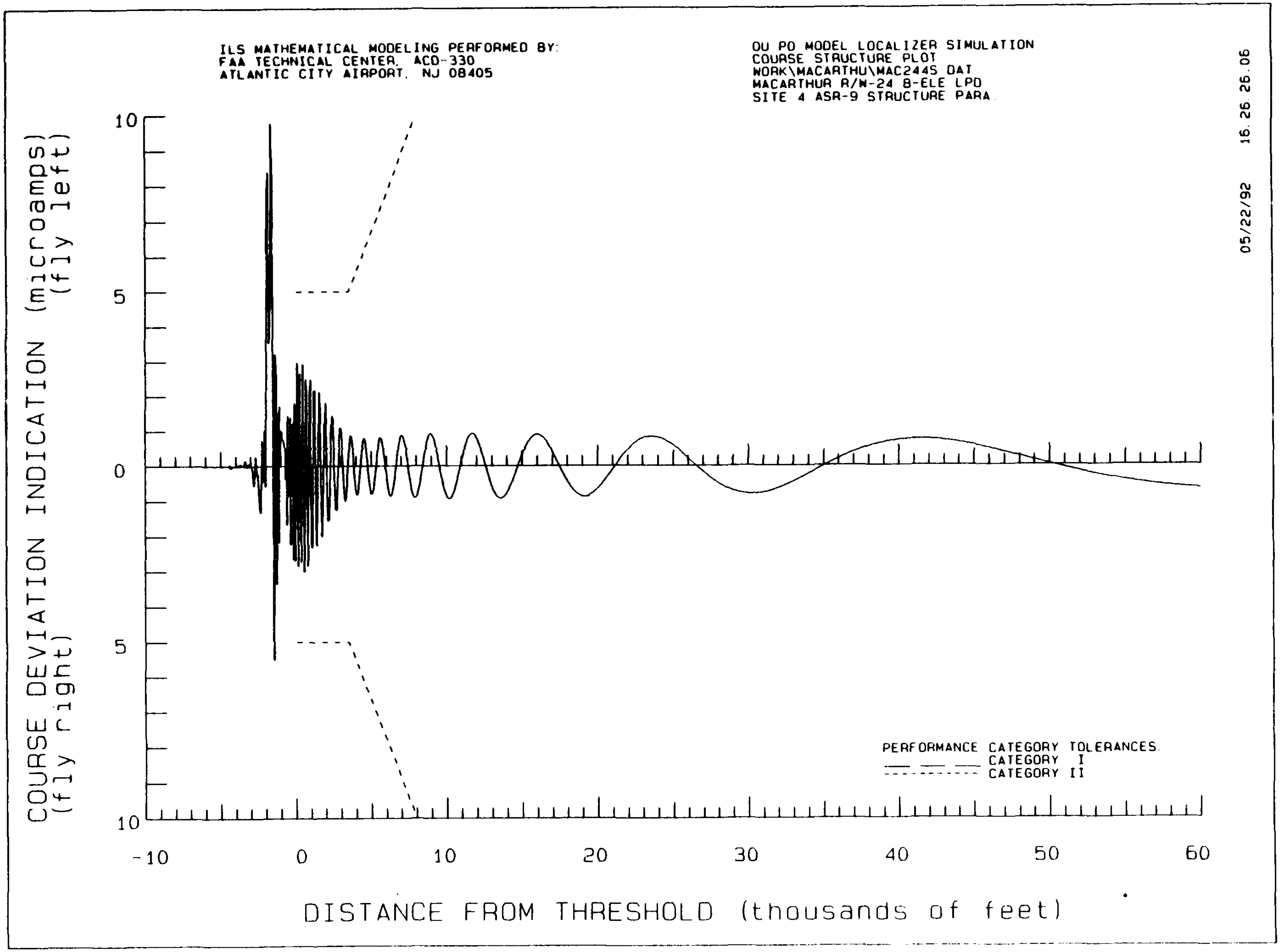

FIGURE 10. COURSE STRUCTURE, LONG ISLAND MACARTHUR AIRPORT RUNWAY 24, ASR-9 STRUCTURE PARALLEL, SITE 4

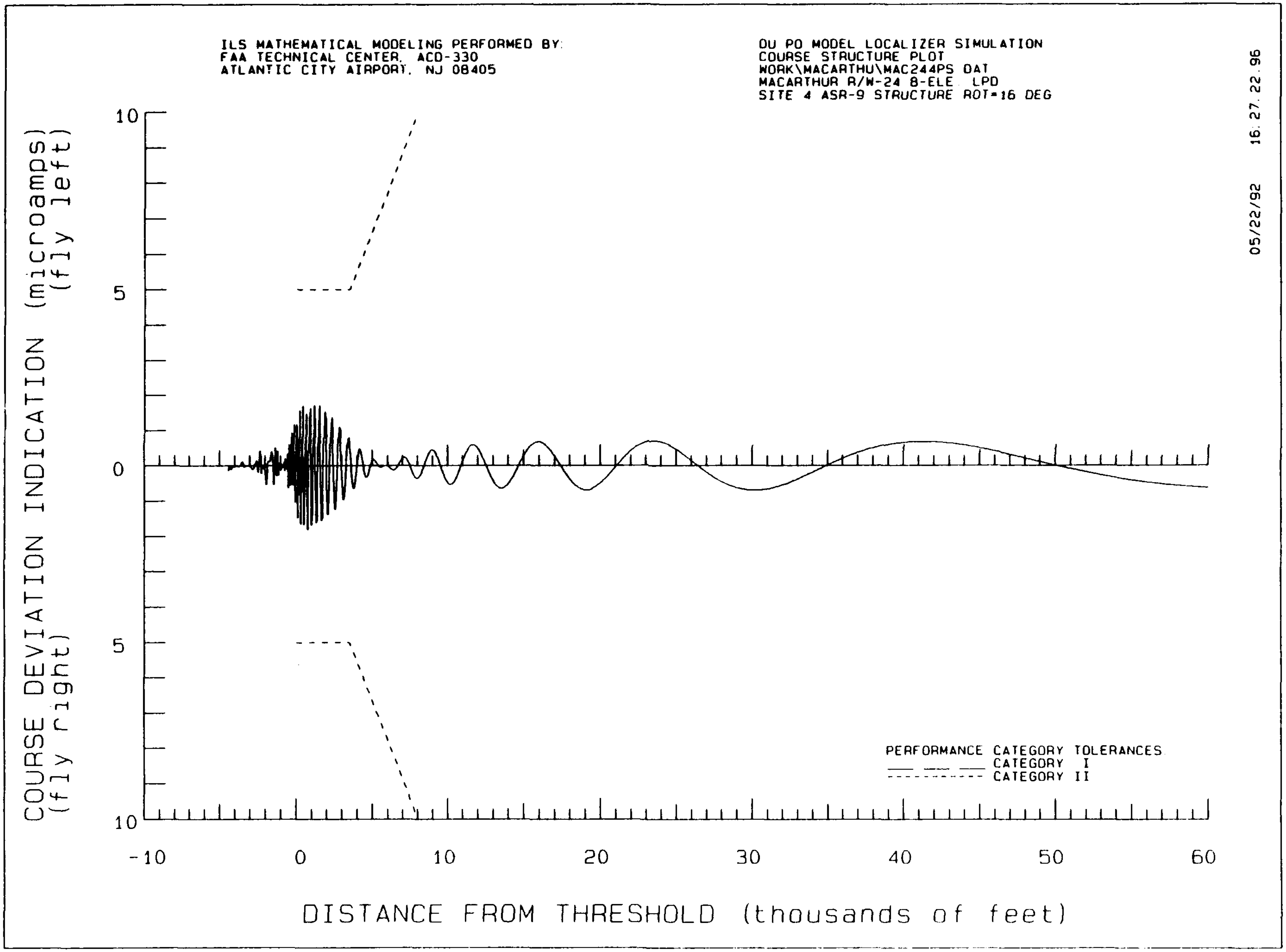

FIGURE 11. COURSE STRUCTURE, LONG ISLAND MACARTHUR AIRPORT RUNWAY 24, ASR-9 STRUCTURE +16 DEGREE ROTATION, SITE 4

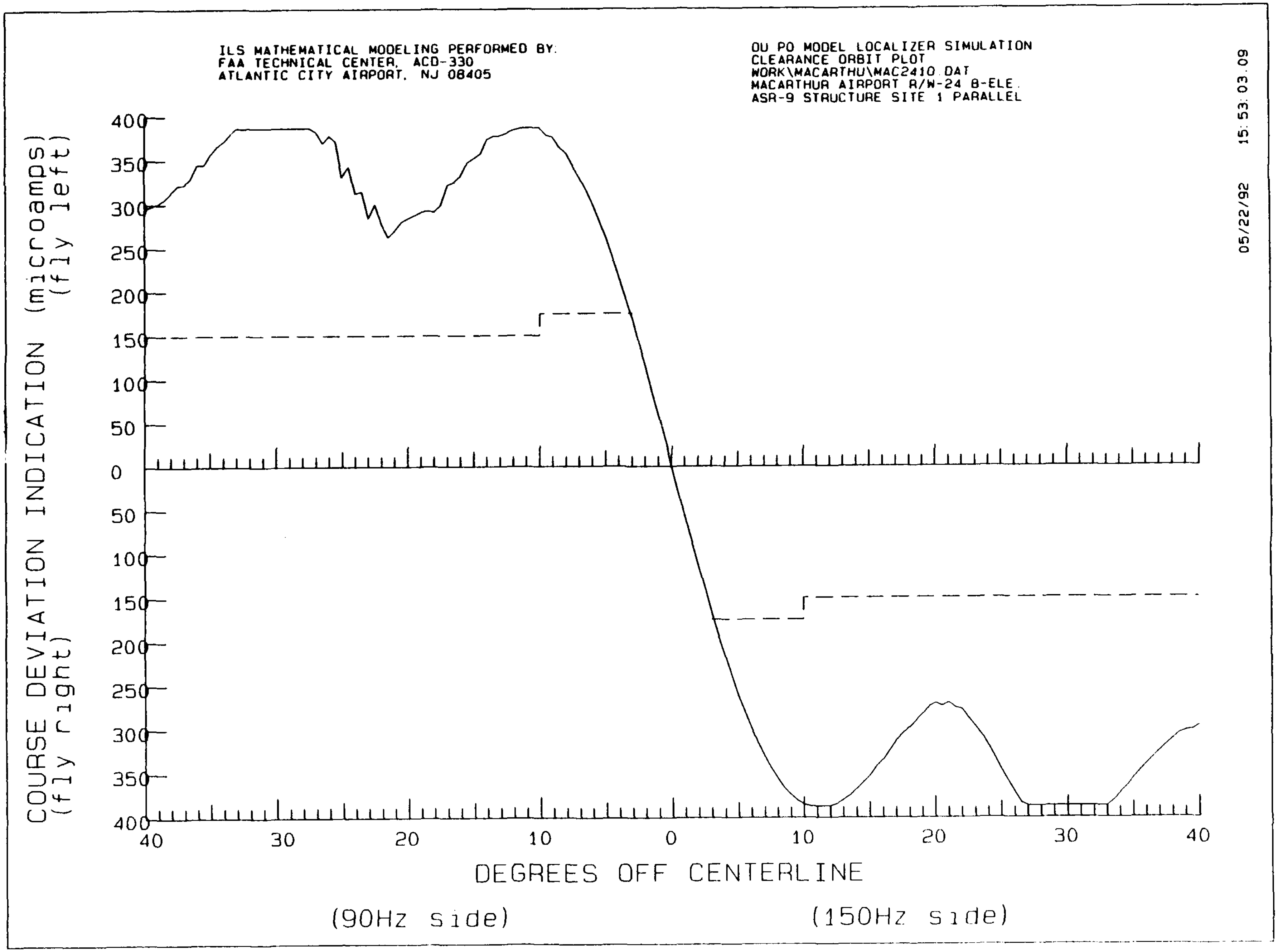

FIGURE 12. CLEARANCE ORBIT, LONG ISLAND MACARTHUR AIRPORT RUNWAY 24, ASR-9 STRUCTURE EFFECTS ONLY

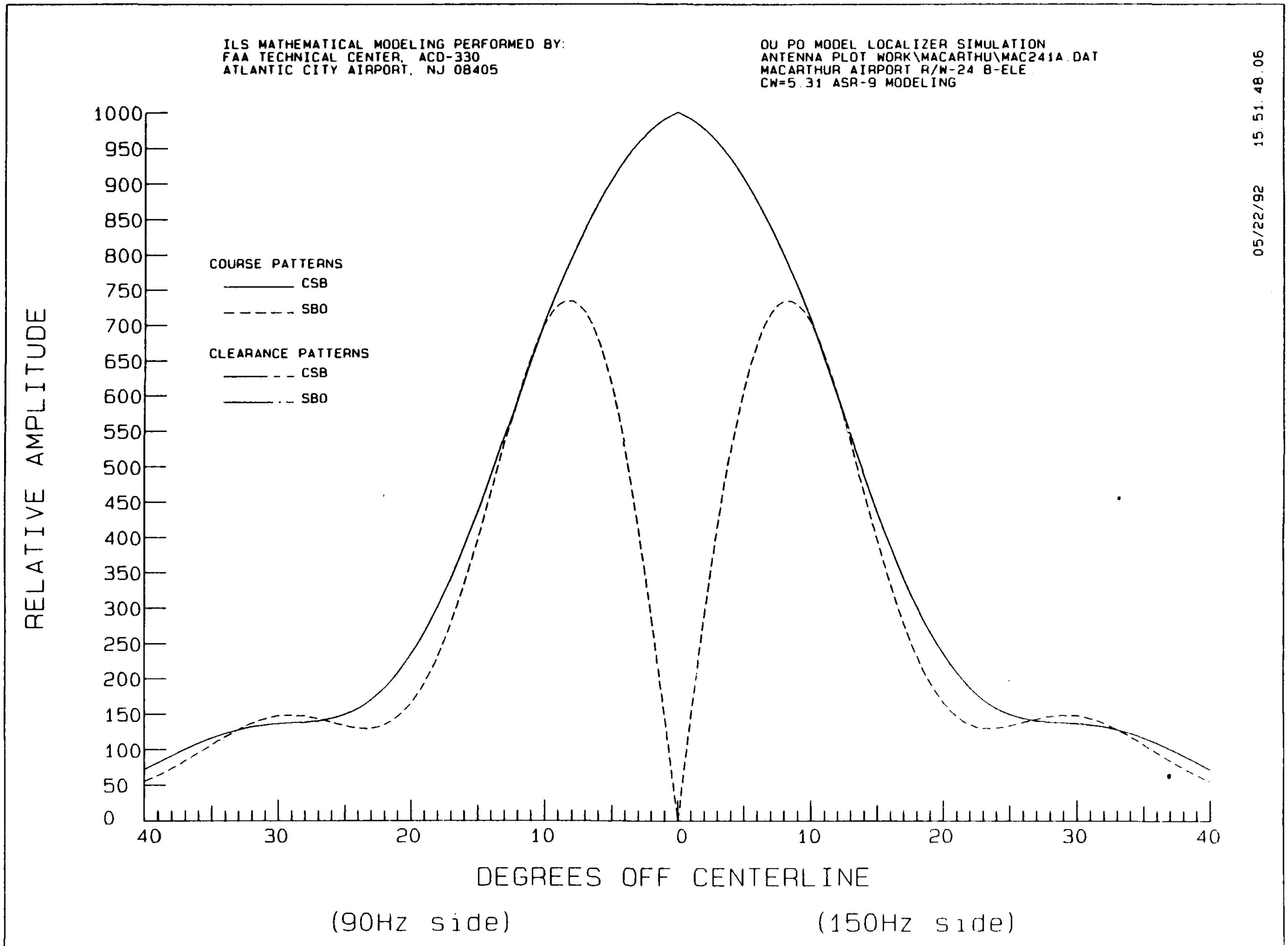

FIGURE 13. CSB AND SBO ANTENNA PATTERNS, LONG ISLAND MACARTHUR AIRPORT RUNWAY 24, 8-ELEMENT LPD ANTENNA